SECTION 15—SENSORS AND LASERS TECHNOLOGY

OVERVIEW

This section covers most sensor types that are of military interest. Inertial, chemical, biological and nuclear sensors are covered in other sections. This section also covers the laser technologies that are not covered in other sections. The sensors included are acoustics for air, terrestrial and marine platforms; electro-optical; gravity meters and gradiometers; lasers; magnetometers and magnetic gradiometers; and radar. Obscurants are included as one method of countering some sensors. The acoustic sensors are used militarily for locating submarines, mines and lost objects; depth sounding; bottom mapping; and weapon activation and homing. They are used commercially for fish finding, seismic exploration at sea and for petroleum and mineral exploitation. Electro-optical sensors are typically used for night vision devices and for terminal guidance for smart weapons. Gravity meters measure gravity magnitude and gravity gradiometers measure gravity gradients. These sensors are used for missile siting, inflight guidance, and to aid in inertial navigation. They are used commercially in geophysical surveys. Military lasers having less than 15 kW output power are used primarily for limited visibility operations and to improve targeting accuracy with guided weapons. Magnetic sensors detect the presence of a magnetic field and measure its magnitude and/or direction and are used militarily for covert detection of submarines and mines and for proximity detection by ordnance fuses. They are used commercially in geophysical surveys. Radar is used militarily on all types of platforms and at fixed sites for detecting and locating targets, for weapon guidance and to obtain information about earth features and atmospheric conditions. Major commercial uses are air traffic control, ship tracking for collision avoidance and weather tracking. Gravity gradiometers, lasers and radar are used in the delivery of WMD. No major emerging technology developments are underway. A large part of sensors and lasers technology is enabling for military applications as they are the eyes and ears of many military systems and provide a great proportion of the data required for prosecution of military activity.

SECTION 15.1—ACOUSTIC SENSORS, AIR AND TERRESTRIAL PLATFORMS

OVERVIEW

This item covers technologies for the development or production of acoustic systems for air platforms and for terrestrial (land-based) applications. Included are the seismic acoustic systems for the location and identification of petroleum producing features within the earth's crust. The processing and computing capability of seismic terrestrial-based processing centers that are considered critical are discussed in the Information Systems section. Passive acoustic terrestrial systems are included for intruder detection and for the detection and location of target vehicles and direct fire weapons. Microphones or geophones are placed as best possible for reception and enhanced signal to noise ratio. Criteria for decision and the selection and weighting of discriminates (clues) is paramount. Aircraft sensors require isolation from acoustic noise caused by air flow, propulsion and other equipment vibration. The acoustic sensors for identifying, selecting and isolating the vibrations are required for noise reduction. Seismic processing and computing capability has been developed 100 percent by the seismic industry. Passive intruder-detection systems have been developed primarily by the military. Aircraft acoustic vibration reduction has been driven by military needs. Current intruder- and vibration-reduction systems were developed by the United States but foreign built systems are now being evaluated.

Table 15.1-1. Acoustic Sensors, Air and Terrestrial Platforms Militarily Critical Technology Parameters

Technology	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
Passive Acoustic Detection and Location of Intruders on Land	Capability to differentiate intruders from background with 98% accuracy	None identified	None identified	Validated set of algorithms for detection and discrimination of intruders	WA ML 5
Passive Acoustic Systems for Locating Direct Fire Weapons on Land	Locate direct fire weapons within 10 m out to 5000 m range	None identified	None identified	Validated set of algorithms to isolate, detect, discriminate, and locate direct fire weapons from a self-generating ground clutter environment.	WA ML 5, 21
Passive Acoustic Detection and Location of Target Vehicles on Land	Target detection, identification and real time position tracking within 10 m out to 5000 m range.	None identified	None identified	Validated set of algorithms for detecting, discriminating and tracking of targets against noise clutter background	WA ML 5
Ground Vehicle Platform-Noise Reduction	> 40 dB reduction	None identified	None identified	Validated set of algorithms using active and passive noise reduction techniques	WA ML 5
Aircraft Self-Noise Reduction	> 6 dB reduction	None identified	None identified	None identified	WA ML 11

SECTION 15.2—ACOUSTIC SENSORS, MARINE, ACTIVE SONAR

OVERVIEW

Most marine sensing systems use sonars which employ acoustic signals (sound waves) to locate underwater objects and to determine features. Sonars are termed *active* when sound is generated by the system for the purpose of echo ranging on a target and passive when listening to the sound radiated by the target. Active sonars are used militarily for antisubmarine warfare (ASW), weapon homing, torpedo defense, mine warfare, swimmer warfare, deep sea salvage, and underwater communications and navigation. Commercial uses include locating fish and other objects, seismic exploration at sea, petroleum and mineral exploitation, and academic studies. Dual use includes the detection, classification, and tracking of underwater objects and features for navigation, depth sounding, and bottom mapping. Active sonar performance is highly dependent on the acoustic environment and frequency of the system. ASW sonars are low frequency, 100 Hz to 10 kHz, to obtain long ranges out to 30 km. Mine detection and deep sea salvage active sonars are generally short range using high frequency, 30 to 750 kHz, to provide the resolution to discriminate and identify the desired targets from background clutter. Underwater weapon active sonars are medium range, on the order of 1000 m, to detect, locate, and track the target and provide steering commands. Marine seismic systems use a towed 8- to 200-Hz frequency source and a long towed hydrophone array (streamer) to receive the sound signals bounced off the ocean bottom and other features in the earth's crust to locate areas that have a potential for petroleum. There are no active sonar technologies known to be directly used for WMD. There is no revolutionary, emerging technology development underway. Approximately 10 percent of active sonar systems, by cost, are commercial and most have dual use potential for major military applications. Most all active sonar development has been driven by military application, including part of the seismic systems.

Table 15.2-1. Acoustic Sensors, Marine, Active Sonar Militarily Critical Technology Parameters

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
ACTIVE SONAR DATA PROCESSING	Cues (discriminants), decision criteria and process for real-time automatic or computer-aided detection, classification, discrimination, or identification of USW targets for data reduction and decision process	None identified	None identified	Validated set of algorithms	WA ML 9
ACTIVE SONAR SIGNAL AND DATA PROCESSING	Empirically validated real-time processing of active acoustic data for fixed or mobile arrays operating in the bistatic, or multistatic mode	None identified	None identified	Validated set of algorithms	WA ML 9
ACTIVE SONAR ADAPTIVE BEAMFORMING	Real-time adaptive with interference rejection > 12 dB	None identified	None identified	Validated set of algorithms	WA ML 4, 9
ACTIVE SONAR BEAMFORMING	< 1° at frequencies < 100 kHz	None identified	None identified	None identified	WA IL Cat 6
ACTIVE SONAR REVERBERATION SUPPRESSION INCLUDING BROADBAND PROCESSING	Track targets having speeds < 3 knots and reduce effect of countermeasures	None identified	None identified	Validated set of algorithms	WA ML 9

(Continued)

Table 15.2-1. Acoustic Sensors, Marine, Active Sonar Militarily Critical Technology Parameters (Continued)

Technology	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
Channel adaptive processing using probe pulse to characterize the medium and utilizing that information in the transmit or receive signal processing	500% increase in reliable data rate and the determination of reliable data rate	None identified	None identified	Validated set of algorithms	WA ML 9
Environmentally adaptive active sonar	The process of matching signal to environmental conditions in order to minimize multiple arrival interference and signal attenuation by 3 dB or more	None identified	None identified	Validated set of algorithms	WA ML 9
Acoustic projectors	Instantaneous radiated acoustic power density > 0.01 $mW/mm^2/Hz$; continuously radiated acoustic power density > 0.001 $mW/mm^2/Hz$, both for frequencies < 10 kHz; designed to withstand pressure at depths >1000 m or sidelobe suppression > 22 dB	None identified	Underwater acoustic anechoic test tank with 2000 psi pressure capability.	None identified	WA IL Cat 6
Acoustic projector using piezoelectric composite or electrostrictive materials	With diameter < 20 cm; submerged life > 10 years; operating < 500 Hz or element sound pressure level > 180 dB (reference to 1 μPa at 1 m)	None identified	None identified	None identified	WA ML 11
Acoustic projector using piezoelectric elements	Uniformity better than ± 2 dB in transmitting voltage or current response or a uniformity of better than 2% in frequency of resonance; or uniformity batch to batch with ± 5% of specified design for dielectric or piezoelectric or electrostrictive constant	None identified	Underwater acoustic test tank.	None identified	WA ML 4, 9
Acoustic projector modeling	Design that predicts actual source level, transmitting voltage or current response within ± 2 dB or resonance at all power levels within ± 2%	None identified	None identified	None identified	WA ML 4, 9
Submersible active sonar for object location and recovery	Feature height finding or beam interpolation using computer aided detection or track, fine angle horizontal or vertical resolution	None identified	None identified	Validated set of algorithms	WA ML 9

(Continued)

Table 15.2-1. Acoustic Sensors, Marine, Active Sonar Militarily Critical Technology Parameters (Continued)

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
SUBMARINE AHEAD LOOKING ACTIVE SONAR	Ahead looking bathymetric sonar using monopulse (interferometric) processing having displays with three dimensional qualities; with system data accuracies better than 0.5% of the average water depth across the swath	None identified	None identified	Validated set of algorithms	WA ML 9
SUBMARINE OR SUBMERSIBLE ACTIVE SONAR DATA PROCESSING	Multi-aspect data fusion processing	None identified	None identified	Validated set of algorithms	WA ML 9
SUBMARINE ACTIVE SONAR TO DETERMINE OVERHEAD ICE THICKNESS WITH ICE HARDENED CONFORMAL TRANSDUCERS	Determine ice thickness with 75% accuracy	None identified	None identified	Validated set of algorithms	WA ML 9
SIDESCAN SONAR	Continuous coverage at > 20 knots speed	None identified	None identified	Validated set of algorithms	WA ML 11
WIDE-SWATH BATHYMETRIC ACTIVE SONAR	Beams less than 1.9° or data accuracies better than 0.3% of the average water depth across the swath	None identified	None identified	None identified	WA IL Cat 6
UNDERWATER WEAPONS ACTIVE SONARS	Multiple preformed beams, transmit frequency > 15 kHz, withstand depth > 500 m, sound pressure level > 220 dB (reference to 1 μPa at 1 m), resolve targets at ranges > 1000 m with angular accuracy better than 5°, or doppler accuracy better than 2 knots.	None identified	None identified	Target recognition and track set of validated algorithms	WA ML 4
ACTIVE SONAR FOR SWIMMER DETECTION, CLASSIFICATION AND TRACK	Narrow beams, computer aided detection, classification and track with low false alarm rate at range of 500 m	None identified	None identified	Target recognition and track set of validated algorithms	WA ML 9
MINE COUNTERMEASURE PLATFORM ACTIVE SONARS	Null steering > 12 dB to remove surface effect interference that blanks targets	None identified	None identified	Validated set of algorithms to track the sea surface	WA ML 9

SECTION 15.3—ACOUSTIC SENSORS, MARINE, PASSIVE SONAR

OVERVIEW

Passive sonars are used militarily for the covert location of underwater objects that radiate acoustic energy and are used primarily for anti-submarine and anti-surface ship warfare. Functions performed are detection, classification, identification and location of acoustically radiating targets, including those being performed by mine actuators and acoustic-homing torpedoes. Passive sonar performance is dependent on the acoustic environment. The major interference is own-ship noise, radiated noise from nearby friendly ships, long-range shipping, and ambient background noise. As submarines have become quieter, the ASW passive sonar band has been extended to the lower few hundred hertz. Propagation paths are the same as for active sonars except the path is one-way only. Thirty to sixty km ranges are possible with towed arrays and hundreds of km ranges are possible from fixed or deployed sites. In littoral areas, the ranges are shorter. Underwater weapon passive sonars are designed to detect targets at ranges out to 20 km, while discriminating the target radiated noise from weapon self-noise, ambient background noise or countermeasures. There are few commercial uses of passive sonar except for academic research. The major concern is with "active" seismic marine towed hydrophone arrays (streamers) and bottom or bay cable systems that can be used in the passive mode for ASW. No passive sonar technologies are known to be directly used for WMD. Most passive sonar development is by evolutionary processes and there is no revolutionary, emerging technology development underway. All basic passive sonar technologies are enabling as they are required for covert, small or large scale ocean sensing. All U.S. Navy passive sonars are U.S. developed and produced. Some advanced technologies are shared with close allies, but relatively few systems are exported.

Table 15.3-1. Acoustic Sensors, Marine, Passive Sonar Militarily Critical Technology Parameters

Technology	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
Intercept Receivers	Full spectrum with bearing determination < 45° error	None identified	None identified	Validated set of algorithms	WA ML 9
Deployed Passive Sonar Systems	Range one convergence zone (CZ) (30 to 60 km) and track multiple targets	None identified	None identified	Processing for irregular array shapes, data rate reduction, data fusion and decision criteria	WA ML 11
Bottom Mounted Passive Sonar System	Range multiple CZ, track multiple targets or > 5-year life	None identified	None identified	Processing for irregular array shapes, and data rate reduction, data fusion and decision criteria	WA ML 11
Sonobuoys Including Active Adjunct Reception	Empirically validated real-time, in buoy processing; incorporating volumetric arrays or providing target bearing with < 45° error	None identified	None identified	Validated set of algorithms	WA ML 11
Underwater Mines and Torpedoes Passive Sensors	Detect, track target radiated noise of targets out to 20 km	None identified	Nose assembly and body machining	Validated set of algorithms	WA ML 4
Passive Target Tracking	Resolve and track multiple targets	None identified	None identified	Validated set of algorithms	WA ML 9

(Continued)

Table 15.3-1. Acoustic Sensors, Marine, Passive Sonar Militarily Critical Technology Parameters (Continued)

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
PASSIVE TARGET BEARINGS	Processor for target bearing accuracy of < 0.5°	None identified	Array installation and alignment and underwater acoustic test range with operating range of 10 km and accuracy of < 0.1 deg.	Validated set of algorithms	WA ML 9
PASSIVE RECEPTION	Computer aided, real-time processing for detection, classification, threat related identification or tracking with capability to detect submarines at speeds < 8 knots at 30 km range using flow and propulsor related noise or using multiple track or multiple line spectra	None identified	None identified	Validated set of algorithms	WA ML 9
PASSIVE RANGING	Ranging < 10 minutes time	None identified	Array installation and alignment	Validated set of algorithms	WA ML 9
FULL SPECTRUM PROCESSING	Full acoustic spectrum with 360° coverage	None identified	None identified	Validated set of algorithms	WA ML 9
PASSIVE SONAR DATA FUSION	In real-time for 2 or more receiving arrays	None identified	None identified	Validated set of algorithms	WA ML 9
PASSIVE SONAR ARRAY NOISE CANCELLATION BY ELECTRONIC PROCESSES	> 2 dB for flow or acceleration noise	None identified	None identified	Validated set of algorithms	WA ML 4, 9
PASSIVE SONAR ADAPTIVE BEAM FORMING, NULL STEERING OR SIDELOBE REDUCTION	> 6 dB interference reduction	None identified	None identified	Validated set of algorithms	WA ML 4, 9
PASSIVE SONAR HULL MOUNTED RECEIVING ARRAYS	Not self noise limited > 12 knots and > 35 m depth using sensor matching or array shading or pressure tolerant processing with > 3 dB self noise reduction	None identified	Array installation and alignment equipment	None identified	WA ML 4, 9
ASW TOWED ARRAYS	Multiple lines, strength member in hose wall, electronic cancellation of flow or acceleration noise, vibration isolation operates > 8 knots tow speed, or low noise, dynamic leveling and depression force > 100 pounds at speed > 8 knots	None identified	None identified	None identified	WA ML 4, 9
TOWED ARRAY DISCRETE POINT LOCATION	Ability to predict within 1m discrete points on a towed array	None identified	None identified	Array shape prediction	WA ML 9
TOWED ARRAY SELF-NOISE MODELING	Ability to predict towed array self-noise levels within 10 dB based on tow speed, array diameter, construction and material properties	None identified	Open ocean acoustic test range	Predict self-noise based on physical characteristics of array	WA ML 9

(Continued)

Table 15.3-1. Acoustic Sensors, Marine, Passive Sonar Militarily Critical Technology Parameters (Continued)

Technology	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
SEISMIC TOWED HYDROPHONE ARRAYS	Longitudinally reinforced hose wall, multiplexed hydrophone group signals designed to operate > 35 m depth, array diameter < 40 mm or hydrophones better than specified below	None identified	None identified	None identified	WA IL Cat 6
SEISMIC BAY OR BOTTOM CABLE SYSTEMS	Multiplexed sensor group signals designed to operate > 35 m depth or hydrophones better than specified below	None identified	None identified	None identified	WA IL Cat 6
HYDROPHONES (TRANSDUCERS)	Continuous flexible sensors or assemblies of discrete sensor elements with dimensions < 20 mm and separation of elements < 20 mm; or using optic fibers, piezoelectric polymers, or piezoelectric composite ceramic material as sensing elements	None identified	Open ocean acoustic test range	None identified	WA IL Cat 6
HYDROPHONES (TRANSDUCERS) WITHOUT PREAMPLIFIERS AND WITH NO ACCELERATION COMPENSATION	Sensitivity better than - 180 dB (reference to 1 V per μPa)	None identified	Acoustic hydrophone calibration facility	None identified	WA IL Cat 6
HYDROPHONES (TRANSDUCER) WITHOUT PREAMPS AND WITH ACCELERATION CANCELLATION	Operates < 35 m depth with sensitivity better than –186 dB (reference to 1 V per μPa), operates at depths > 35 m and sensitivity better than –192 dB, operates at depths > 100 m and sensitivity better than –204 dB; designed for operation at depths > 1000 m.	None identified	Acoustic hydrophone calibration facility	None identified	WA IL Cat 6
HYDROPHONES INCORPORATING PREAMPLIFIERS	Detection threshold < sound pressure spectrum defined by (90–16 log (freq. in Hz)) expressed in dB reference to 1 μPa and operates > 35 m depth and having dimension < 3 cm	None identified	Acoustic hydrophone calibration facility	None identified	WA ML 4, 9
TOWED ARRAY HYDROPHONES	Acceleration voltage response divided by voltage sensitivity is < 135 dB reference to 1 μPa/g measured in air	None identified	Vibration and acoustic hydrophone test fixtures	None identified	WA ML 9
HULL MOUNTED HYDROPHONE	Acceleration voltage response divided by voltage sensitivity is < 150 dB reference to 1 μPa/g measured in water over band 10–10,000 Hz	None identified	Vibration and acoustic hydrophone test fixtures	None identified	WA ML 9
HULL MOUNTED HYDROPHONES MOUNTINGS	> 12 dB velocity reduction and > 4 dB in echo reduction for frequency < 10 kHz and operating depths > 35 m	None identified	Quality control and uniformity of manufacturing	None identified	WA ML 9
HYDROPHONES FOR DETECTING ACOUSTIC PARTICLE VELOCITY	Operate at depths > 35 m and within 25% of neutrally buoyant	None identified	None identified	None identified	WA ML 9

SECTION 15.4—ACOUSTIC SENSORS, MARINE PLATFORM

OVERVIEW

This item covers marine platform acoustics, which encompasses all measures taken to reduce the self-noise of ships, submarines, or other sonar platforms. Platform acoustic technologies have a major impact on the sonar system capability by the reduction of self-noise generated by own ship machinery or water flow around the platform. Specifically of interest are domes; baffles; machinery quieting including main propulsion, valves, gears, pumps, fans, balancing, and mounting of same, measurement techniques and instrumentation; hull coatings; and active and passive structural acoustic noise control. Some of these items are partially covered under signature reduction in MCTL Section 12 on Marine Systems. Radiated noise that is under marine systems and ship self-noise that impacts sonars often come from the same sources but the process for reduction of these noises can be quite different and separate. There are no known commercial uses for the large acoustic domes and windows that are considered militarily critical. No marine platforms are known to be directly used in WMD. No emerging technology development is underway. Most marine platform acoustic processes are enabling as the platform is required to operate both the multitude of active and passive sonar systems. All self-noise reduction for marine platforms has been driven by military application. Most acoustic processes covered in this section were developed by the U.S. Navy.

Table 15.4-1. Acoustic Sensors, Marine Platform Militarily Critical Technology Parameters

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
ACOUSTIC DOMES AND WINDOWS	< 2 dB insertion loss at normal incidence > 15 kHz, submerged > 5 years, withstand wave slap, highly damped or nonpropagation of structural defect	None identified	Underwater acoustic test range for frequency > 15 kHz	None identified	WA ML 9
BAFFLES, DECOUPLERS AND ABSORBERS FOR SUBMARINES	Pressure release or absorption 80% effective over depth excursion of submarines.	None identified	Underwater anechoic acoustic test facility with pressure of 1000 psi	None identified	WA ML 9
ACOUSTIC REFLECTORS AND LENS	Function 80% effective over depth excursion of submarines	None identified	Underwater anechoic acoustic test facility with pressure of 1000 psi	None identified	WA ML 9
ACOUSTIC BAFFLES, CONDITIONERS, AND DECOUPLERS	Noise reduction > 10 dB for frequencies < 2 kHz or > 20 dB for frequencies from 2 to 5 kHz; both for depths > 35 m.	None identified	Underwater anechoic acoustic test facility with pressure of 1000 psi	None identified	WA ML 9
ACTIVE OR PASSIVE NOISE CANCELLATION SYSTEMS	Noise cancellation > 6 dB.	None identified	None identified	None identified	WA ML 9

SECTION 15.5—ELECTRO-OPTICAL SENSORS

OVERVIEW

This section covers critical military applications of electro-optical "Sensors Systems" used in various tactical and strategic missions, other than in space. Sensors designed and radiation hardened for space applications are covered in the Space section. The sensor systems covered here are based on either *thermal imaging* or *image intensification* technology. Collectively, these systems are more commonly known as *Night Vision Systems.*

Table 15.5-1. Electro-Optical Sensors Militarily Critical Technology Parameters

Technology	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
Image intensifiers "Second Generation"	Electrostatically focused image intensifier tubes, employing multialkali photocathodes, e.g., S-20 or S-25, microchannel plate electron amplifiers (multipliers) and fiber optic faceplates and a luminous sensitivity > 240 μA/Lumen.	None identified	Equipment for production of fiber optic face plates, fabrication of multialkali photocathodes and micronchannel plate amplifiers.	None identified	WA IL Cat 6 WA ML 15
Image intensifiers "Third Generation"	Electrostatically focused image intensifier tubes, employing III-V compound semiconductor photocathodes and microchannel plate electron amplifiers and a radiant sensitivity > 10 mA/watt.	None identified	Equipment for production of fiber optic face plates, fabrication of compound semiconductor photocathodes and microchannel plate amplifiers.	None identified	WA IL Cat 6 WA ML 15
Inverters, fiber optic, for image intensifiers	Diameter < 25 mm	None identified	None identified	None identified	WA IL Cat 6 WA ML 15
Cooled arrays, scanning and staring - Indium Antimonide (In Sb)	Arrays having 256 elements or more.	InSb	Epitaxial growth equipment capable of producing a layer thickness uniform to < ± 2.5% across 75 mm.	None identified	WA IL Cat 6 WA ML 15
Cooled, scanning arrays - Mercury Cadmium Telluride (MCT)	Arrays having more than 60 elements, or incorporating Time Delay and Integration (TDI) within the element and having four (4) elements or more.	HgCdTeg Low Defect CdTe substrates	Epitaxial growth equipment capable of producing a layer thickness uniform to < ± 2.5% across 75 mm.	None identified	WA IL Cat 6 WA ML 15
Cooled, staring arrays - Mercury Cadmium Telluride (MCT)	Arrays having 256 elements or more.	HgCdTeg Low Detect CdTe substrates	Epitaxial growth equipment capable of producing a layer thickness uniform to < ± 2.5% across 75 mm.	None identified	WA IL Cat 6 WA ML 15

(Continued)

Table 15.5-1. Electro-Optical Sensors Militarily Critical Technology Parameters (Continued)

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
UNCOOLED ARRAYS, STARING, BARIUM STRONTIUM TITANATE OR MICROBOLOMETERS	Arrays having more than 8,000 elements	Barium Strontium Titanate, Lead Zironate	None identified	None identified	WA IL Cat 6 WA ML 15
COOLED OR UNCOOLED ARRAYS, PLATINUM SILICILE	Arrays having more than 10,000 elements	PtSi	None identified	None identified	WA IL Cat 6 WA ML 15
INFRARED DETECTOR COOLERS - CRYOGENIC	Cooling source temperature below 218 K and MTTF or MTBF exceeding 2,500 hours. Joule-Thompson (JT) mini-coolers, self regulating, with an outside bore less than 8 mm.	None identified	None identified	None identified	WA IL Cat 6 WA ML 15

SECTION 15.6—GRAVITY METERS AND GRAVITY GRADIOMETERS

OVERVIEW

This technology can be used to measure a body's (such as the earth's) gravity field, which in turn has applications for detection and localization of mass distributions, covert position determination and inertial navigation compensation. Gravity meters can be used in a static or dynamic base mode to measure gravity magnitude. The gravity gradiometer is used to measure the difference over some known distance. Gravity data are used to estimate vertical deflection and other gravity field components. The knowledge of this influence can be used for detection of man-made or natural mass differences. Since gravity and spatial accelerations are not separable, all inertial navigation and guidance systems require direct or indirect compensation based on knowledge of the gravity field. The indirect, and most common, method uses map data computed from gravity meter surveys. The direct method uses real-time compensation of the local gravity vector to remove the largest uncompensated error left in inertial navigation systems. Compensation can be in real time or post processing for a moving base/platform. Several operational problems arise when gravity meters and gravity gradiometers are deployed on a mobile platform in such applications as geophysical exploration. Since most gravity meters and gravity gradiometers are sensitive to orientation with respect to the earth's gravity field, motion of the sensor in the earth's field will generate spurious signals or "noise" that can degrade the detection capability. Compensator systems and associated software are required to facilitate real-time cancellation of motion-generated noise. The resulting stabilized hybrid system provides the military with a non-emanating, non-jammable, totally *covert* system that can be used worldwide for navigation. Sensor array compensation can reduce spatial and temporal noise.

Table 15.6-1. Gravity Meters and Gravity Gradiometers Militarily Critical Technology Parameters

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
GRAVITY METERS (GRAVIMETERS) GROUND USE	Ground use-static accuracy of < 50 microgal	None identified	Test, calibration, or alignment equipment to calibrate gravimeters with a static accuracy of < 50 microgal. Accelerometer axis align stations.	Algorithms and verified data for real-time gravity compensation and detection (improvement > 10 to 1) for operation using arrays.	WA IL Cat 6 WA ML 9 MTCR 12
GRAVITY METERS (GRAVIMETERS) MOBILE USE	Mobile use accuracy of < 700 microgals with a time-to-steady-state registration of less than 2 minutes under any combination of attendant corrective compensation and motional influences.	None identified	Test, calibration, modeling, compensation or alignment equipment to obtain mobile accuracy of < 700 microgals. Accelerometer axis align stations.	Algorithms and verified data for real-time gravity compensation and detection (improvement > 10 to 1) for operation on mobile platforms and/or using arrays.	WA IL Cat 6 WA ML 9 MTCR 12
GRAVITY GRADIOMETERS GROUND USE	Static platform < 2.5 Eotvos/root Hz	None identified	Test, calibration, modeling, compensation or alignment equipment to obtain static accuracy of < 2.5 Eotvos/root Hz. Accelerometer axis align stations.	Algorithms and verified data for real-time gravity compensation and detection (improvement > 10 to 1) for operation using arrays.	WA IL Cat 6

(Continued)

Table 15.6-1. Gravity Meters and Gravity Gradiometers Militarily Critical Technology Parameters (Continued)

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
GRAVITY GRADIOMETERS MOBILE USE	Moving platform < 10 Eotvos/root Hz	None identified	Test, calibration, modeling, compensation or alignment equipment to obtain mobile accuracy of < 10 Eotvos/root Hz. Accelerometer axis align stations.	Algorithms and verified data for real-time gravity compensation and detection (improvement > 10 to 1) for operation on mobile platforms and/or using arrays.	WA IL Cat 6

SECTION 15.7—LASERS

OVERVIEW

This section covers critical military applications of low power lasers (those having less than 15 kW output power) which are used in various tactical and strategic military systems, other than in directed energy systems. *Directed energy lasers are covered in the Directed Energy Weapons section.* Tunability and wavelength diversity are critical for optical counter and counter-countermeasures. Brightness and beam collimation contribute to greater range capability.

Table 15.7-1. Lasers Militarily Critical Technology Parameters

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
SOLID STATE/TUNABLE LASERS, WAVELENGTH BETWEEN 600 AND 1400 NM	Output energy > 1 J/pulse *and* a pulsed peak power > 20 W.	Ti:Al_2O_3Tm:YSGG, Cr:$BeAl_2O_4$ and alexandrite	None identified	None identified	WA IL Cat 6
SOLID STATE/TUNABLE LASERS, WAVELENGTH EXCEEDING 1400 NM	Output energy > 50 mJ/pulse *and* a pulsed peak power > 1 W *or* an average or CW output power exceeding 1 W.	Tm:YAG, Tm:YSGG, optical parametric amplifiers (OPO)	None identified	None identified	WA IL Cat 6
ND:DOPED, PULSE-EXCITED, MODE-LOCKED, Q-SWITCHED	Pulse duration < 1 ns *and* a peak power > 5 gW, an average output power > 10 W; *or* a pulsed energy > 0.1 J.	None identified	None identified	None identified	WA IL Cat 6
ND:DOPED; PULSE-EXCITED, Q-SWITCHED, MULTIPLE TRANSVERSE MODE	Pulse duration ≥ 1 ns *and* a multiple transverse mode output with a peak power > 400 MW, an average output power > 2 kW; *or* a pulsed energy > 2 J.	None identified	None identified	None identified	WA IL Cat 6
ND:DOPED; PULSE-EXCITED, Q-SWITCHED, SINGLE TRANSVERSE MODE	Pulse duration ≥ 1 ns *and* a single transverse mode output with a peak power > 100 MW, an average output power > 20 W; *or* a pulsed energy > 2 J.	None identified	None identified	None identified	WA IL Cat 6
ND:DOPED; PULSE-EXCITED, NON-Q-SWITCHED, SINGLE TRANSVERSE MODE	A single transverse mode output with a peak power > 500 kW, an average output power > 150 W.	None identified	None identified	None identified	WA IL Cat 6
ND:DOPED; PULSE-EXCITED, NON-Q-SWITCHED, MULTIPLE TRANSVERSE MODE	A multiple transverse mode output with a peak power >1 mW, or an average or CW output power > 2 kW.	None identified	None identified	None identified	WA IL Cat 6
SEMICONDUCTOR LASERS; SINGLE TRANSVERSE MODE DIODES	Wavelength > 1050 nm or average output power exceeding 100 mW.	None identified	None identified	None identified	WA IL Cat 6
SEMICONDUCTOR LASERS - MULTIPLE TRANSVERSE MODE	Output energy > 500 micro joules/pulse and a peak pulsed power > 10 W, *or* an average or CW power > 10 W.	None identified	None identified	None identified	WA IL Cat 6

SECTION 15.8—MAGNETOMETERS AND MAGNETIC GRADIOMETERS

OVERVIEW

Magnetic sensor systems detect and display the presence of a magnetic field and measure its magnitude and/or direction. This unique and enabling technology can be used to *detect and locate* an adversary, *detect* magnetic heading, or determine own position from a database reference. Magnetic sensors are used on many military platforms. Some magnetic sensors, using different technologies, are sensitive to their orientation with respect to the vector components of the local magnetic field; others are not. Some are capable of measuring the absolute level of an ambient magnetic field and its variations; others can only measure variations. Magnetic sensor systems can be configured to detect the spatial variation of the magnetic field intensity from sources external to the instrument, that is, the gradient of the magnetic field intensity, and in this mode are called magnetic gradiometers. Magnetic gradiometers can consist of two magnetic sensors or consist of a single intrinsic magnetic gradient sensor. Magnetometers or magnetic gradiometers use sensors that incorporate militarily critical technologies (see Fig. 15.8-1). Superconductive Quantum Interference Devices (SQUID), electron resonance/optically pumped, nuclear precession, fiber optic, fluxgate, torsion or induction coil. Computational techniques for real-time compensation and detection for operation on mobile platforms are militarily critical. Using other computational techniques, databases with prior or real time magnetic field data from magnetometer arrays can be used to reduce the spatial and temporal background noise of the sensor for detection and classification of intruding vehicles in the sea and on land.

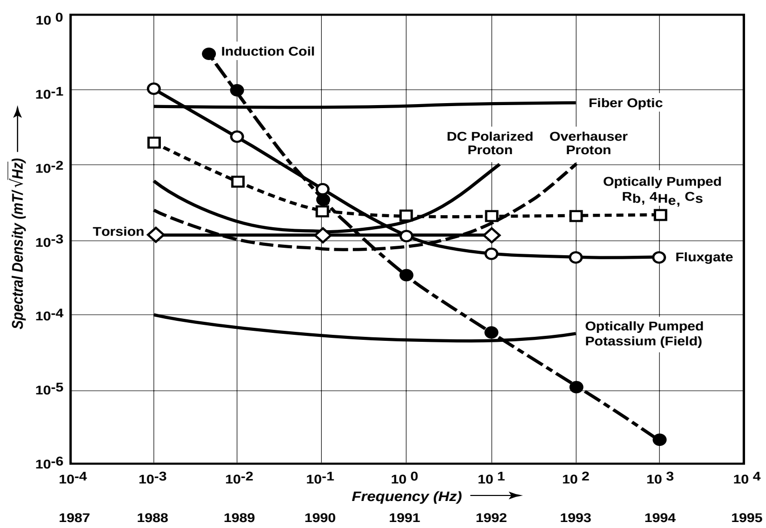

Figure 15.8-1. Magnetometer Characteristics

Table 15.8-1. Magnetometers and Magnetic Gradiometers Militarily Critical Technology Parameters

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
MAGNETOMETERS-SQUID	Noise level < 0.05 nanotesla (nT) rms/root Hz	None identified	Magnetic contamination control area with field gradient < 0.1 nT/meter	Algorithms and verified data for real-time magnetic compensation and detection (improvement > 10 to 1) for operation on mobile platforms and/or using arrays.	WA ML 4, 9 WA IL Cat 6

(Continued)

Table 15.8-1. Magnetometers and Magnetic Gradiometers Militarily Critical Technology Parameters (Continued)

Technology	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
Magnetometers-Electron Resonance/ Optically Pumped (^{4}He, R_B, Cesium, etc.)	Noise level < 0.05 nT rms/root Hz	None identified	Magnetic contamination control area with field gradient < 0.1 nT/meter	Algorithms and verified data for real-time magnetic compensation and detection (improvement > 10 to 1) for operation on mobile platforms and/or using arrays.	WA ML 4, 9 WA IL Cat 6
Magnetometers-Nuclear Precession (Proton/Overhauser)	Noise level < 0.05 nT rms/root Hz	None identified	Magnetic contamination control area with field gradient < 0.1 nT/meter	Algorithms and verified data for real-time magnetic compensation and detection (improvement > 10 to 1) for operation on mobile platforms and/or using arrays.	WA ML 4, 9 WA IL Cat 6
Magnetometers-Induction Coil	Noise level < 0.05 nT rms/root Hz at frequencies < 1 Hz or 1×10^{-2}nT rms/root Hz > 1 Hz and < 10 Hz or 1×10^{-2} nT rms/root Hz > 10 Hz	None identified	Magnetic contamination control area with field gradient < 0.1 nT/meter	Algorithms and verified data for real-time magnetic compensation and detection (improvement > 10 to 1) for operation using arrays.	WA ML 4, 9 WA IL Cat 6
Magnetometers-Fiber Optic	Noise level < 1.0 nT rms/root Hz	None identified	Magnetic contamination control area with field gradient < 0.1 nT/meter	Algorithms and verified data for real-time magnetic compensation and detection (improvement > 10 to 1) for operation on mobile platforms and/or using arrays.	WA ML 4, 9 WA IL Cat 6
Magnetometers-Flux Gate (Valve)	Noise level < 0.05 nT rms/root Hz at frequencies < 1 Hz and 10^{-2} nT rms per square root Hz at > 1 Hz	None identified	Magnetic contamination control area with field gradient < 0.1 nT/meter	Algorithms and verified data for real-time magnetic compensation and detection (improvement > 10 to 1) for operation on mobile platforms and/or using arrays.	WA ML 4, 9
Magnetometer-Torsion	Noise level < 0.05 nT rms/root Hz	None identified	Magnetic contamination control area with field gradient < 0.1 nT/meter	Algorithms and verified data for real-time magnetic compensation and detection (improvement > 10 to 1) for operation on mobile platforms and/or using arrays.	WA ML 4, 9
Magnetic Gradiometers Using Multiple Magnetometers	Noise level of individual magnetometers of < 0.05 nT rms/root Hz	None identified	Magnetic contamination control area with field gradient < 0.1 nT/meter	Algorithms and verified data for real-time magnetic compensation and detection (improvement > 10 to 1) for operation on mobile platforms and/or using arrays.	WA ML 4, 9 WA IL Cat 6

(Continued)

Table 15.8-1. Magnetometers and Magnetic Gradiometers Militarily Critical Technology Parameters (Continued)

Technology	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
Magnetic Gradiometer-Fiber Optic	Noise level of < 0.3 nT/meter rms/root Hz	None identified	Magnetic contamination control area with field gradient < 0.1 nT/meter	Algorithms and verified data for real-time magnetic compensation and detection (improvement > 10 to 1) for operation on mobile platforms and/or using arrays.	WA ML 4, 9 WA IL Cat 6
Intrinsic Magnetic Gradiometer Using Other Than Fiber Optics	Noise level of < 0.015 nT/meter rms/root Hz	None identified	Magnetic contamination control area with field gradient < 0.1 nT/meter	Algorithms and verified data for real-time magnetic compensation and detection (improvement > 10 to 1) for operation on mobile platforms and/or using arrays.	WA ML 4, 9 WA IL Cat 6
Non-Magnetic Closed Cycle Refrigeration Equipment	Operation < 103 deg K	None identified	Magnetic contamination control area with field gradient < 0.1 nT/meter	None identified	WA ML 4, 9

SECTION 15.9—OBSCURANTS

OVERVIEW

Obscurants are materials that limit or prevent reconnaissance, surveillance, target acquisition, and weapon guidance. They can be used on the battlefield to enhance friendly operations and/or degrade enemy operations. Obscurants can be identified by their impact on the electromagnetic (EM) spectrum, e.g., ultraviolet (UV); visible; infrared (IR); millimeter wave (mmW); centimeter wave (cmW); above cmW; and multispectral. The major near-term US efforts consist of the following: production and fielding of a large area visual/IR obscurant generator (mechanized and motorized); production and fielding of a self-protection grenade for armored vehicles that defeats sensors in the visual, IR, and mmW; and demonstrating the feasibility of an mmW obscurant generating system to prevent threat radars from observing, acquiring, targeting, and tracking friendly targets. A long-term goal is to validate the capability of multispectral materials to obscure or defeat enemy reconnaissance, surveillance, targeting, and acquisition assets in broad bands of the EM spectrum from visual through mmW.

Table 15.9-1. Obscurants Militarily Critical Technology Parameters

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
MID- AND FAR-INFRARED — SCATTERING; ABSORBING	$Ext_{IR} > 1.5$; packing density > 50% of the material density; dissemination efficiency > 50% of the packaged material.	Conductive flakes (brass, aluminum, graphite); submicron-diameter conductive fiber	Aerosol test chambers; transmissometers; test ranges; nephelometers	Obscurant modeling	WA ML 4 WA IL Cat 1
MILLIMETER WAVE — SCATTERING	$Ext_{MM} > 2$; packing density > 50% of the material density; dissemination efficiency > 50% of the packaged material.	Metal - microwires; metal coated fibers	Aerosol test chambers; transmissometers; test ranges; nephelometers	Obscurant modeling	WA ML 4 WA IL Cat 1
MILLIMETER WAVE — ABSORBING	$Ext_{MM} > 2$; packing density > 50% of the material density; dissemination efficiency > 50% of the packaged material.	Carbon fiber; conductive polymers	Aerosol test chambers; transmissometers; test ranges; nephelometers	Obscurant modeling	WA ML 4 WA IL Cat 1

SECTION 15.10—RADAR

OVERVIEW

Radar systems consist of power supplies, transmitter chains and final amplifiers, antennas, receivers and signal processors, and (usually) displays. Radar is indispensable for a wide variety of military uses, being installed on the ground, on ships, aircraft and missiles for search and localization of enemy and friendly vehicles and installations of all types. The important radar technologies involve bandwidth control, stability for coherent operation, and advanced software for signal processing. Development activity involves solid state modules integrated with antenna elements for active aperture radar. The goal of automatic target recognition (ATR) is being pursued experimentally in many defense communities. Millimeter radars are candidates for missile seeker heads, some for WMD. Another emerging technology employs low frequency (Low UHF) for foliage and ground penetration. As a class, all radar technologies are uniquely enabling since no other detection schemes are capable of ranging and direction finding in the atmosphere in the variety of obstructing conditions (darkness, rainfall, etc.) and at the requisite distances.

Table 15.10-1. Radar Militarily Critical Technology Parameters

TECHNOLOGY	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
MILLIMETER RADAR	Operating freq. between 40 and 230 GHz, average power > 100 milliwatts	None identified	None identified	None identified	WA IL Cat 6
WIDE OPERATING BAND RADAR	> 20% of center frequency; multiband operation and average power > 200 watts	None identified	None identified	None identified	WA ML 3
WIDE INSTANTANEOUS BANDWIDTH RADAR	> 60 MHz bandwidth	None identified	None identified	Pulse compression phase coding; anti-multipath/clutter algorithms	WA ML 5
SPACE-BASED SYNTHETIC APERTURE RADAR (SAR)	Resolution 3 meters or better; displaced phase center	None identified	Space environmental chambers	None identified	WA ML 5
AIRBORNE SYNTHETIC APERTURE RADAR (SAR)	Resolution 3 meters or better	None identified	None identified	Fast algorithms for imaging; efficiency for intensive computations	WA ML 5
INVERSE SYNTHETIC APERTURE RADAR (ISAR)	Resolution of ship target roll, pitch and yaw in sea state 2 and above and better than 0.5 meter	None identified	None identified	Resolution algorithms; fusion with radar signal modulation	WA ML 5
PHASED ARRAY RADAR (GENERAL)	Instantaneous beam agility; interleaved functions; - beam switch time of 20 ms or less; space-time adaptive processing	None identified	None identified	Threat and target priority identification	WA ML 5
PHASED ARRAY RADAR (ADAPTIVE SIGNAL PROCESSING)	Adaptive signal processing (50 dB antenna sidelobe nulls); switching rate of 100 ms or less	None identified	None identified	None identified	WA ML 5
AIRBORNE DOPPLER RADAR (CLUTTER CANCELLATION)	Clutter cancellation of 40 dB or better	None identified	None identified	None identified	WA ML 5
AIRBORNE INTERFEROMETER RADAR	Precision phase and amplitude channel tracking of 98%	None identified	None identified	None identified	WA ML 5

(Continued)

Table 15.10-1. Radar Militarily Critical Technology Parameters (Continued)

Technology	Militarily Critical Parameters Minimum Level to Assure US Superiority	Critical Materials	Unique Test, Production, and Inspection Equipment	Unique Software and Parameters	Control Regimes
Radar pulse compression	Pulse compression ratio > 500; compressed pulse width < 100 nanosecond	None identified	None identified	None identified	WA IL Cat 6
Radar antenna sidelobe control	Lower than 35 dB first sidelobe peak, lower than 45 dB average relative to the main beam peak in a ± 30 degree sector centered on the main beam axis	None identified	Computer numerical controlled (CNC) machine	None identified	WA ML 5
Heightfinding	Time difference on multiple echos > 0.3 ms separation	None identified	None identified	None identified	WA IL Cat 6
Ground radar	Range > 500 km for target size of 1 m^2 or greater	None identified	None identified	Threat and target priority identification	WA ML 5
Laser radar	Space-qualified with coherent detection or angular resolution of 8 microradians	None identified	None identified	Imaging algorithms	WA ML 5 WA ML 15 MTCR 11
Combined (multi-function aperture) radar	Antenna components that attenuate each band less than 5%	None identified	None identified	None identified	WA ML 5
Test range radar	Angular resolution better than 3 milliradians; range resolution better than 10 m rms; velocity resolution better than 3m/sec	None identified	None identified	None identified	WA ML 5 MTCR 12
Radomes	Hardening; thermal shock > 100 cal/sq cm, with peak overpressure > 50 kPa; nonspherical design; boresight error slope accuracy; frequency selective surfaces	None identified	None identified	Taper software for linear boresight accuracy and sidelobe control	WA ML 11 MTCR 12